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STUDIES ON THE STRATOSPHERE AND THE POSSIBLE EFFECTS OF STRATOSPHERIC POLLUTION

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INTRODUCTION

In the U.K. there has long been a tradition of stratospheric research starting with the work of Dobson and his colleagues at Oxford and continuing steadily up to the present with close co-operation between the Meteorological Office and the universities. In addition to the earlier work, surface observations of total ozone have been made regularly using Dobson instruments at a number of British stations both in the U.K. and abroad since the early 1950s.

The Brewer instrument for measuring ozone amounts electrochemically was developed for use on balloons, in aircraft and for research purposes generally. Measurements of winds, temperatures, radiation and humidity in the upper atmosphere have also been made by a variety of methods using radio sondes, satellites and aircraft. A great deal of information was gained from studies carried out by the U.K. Atomic Energy Authority and others of the injection of radioactive isotopes into the upper atmosphere during the various nuclear weapon testing programmes. Laboratory and theoretical studies of ozone were also made in the universities, particularly at Oxford, and the Meteorological Office was well advanced in the development of tropospheric general circulation models and had made studies using low resolution models of the radiative and dynamical aspects of the stratosphere and mesosphere by the late 1960s. Consequently there was considerable background and expertise available in the U.K. on stratospheric studies when in the early 1970s as a result of concern over the possible effects of the exhaust fumes of supersonic aircraft in the stratosphere, general attention was attracted internationally to the possibility that human activities might produce serious effects on the environment by disturbing the natural balance.

This subject was then studied in the U.K. in conjunction with projected Concorde aircraft operations and a major research programme was carried out between 1972 and 1975 on possible effects of stratospheric aircraft under the direction of an expert committee (COMESA) as described in the next section. The overall results of this work were broadly in agreement with those of similar programmes in the U.S.A. and in France, but clearly further work is necessary and other possible pollutants have to be considered. Subsequently a formal Tripartite Agreement was made in May 1976 between France, U.S.A. and U.K. to maintain close collaboration in stratospheric monitoring and research. This present report is an extension of the U.K. first six-monthly report (Nov. 1976) made under the Tripartite Agreement.

COMMITTEE ON METEOROLOGICAL EFFECTS OF STRATOSPHERIC AIRCRAFT (COMESA)

In 1972 COMESA was set up to direct and co-ordinate a programme of research, initially of 3 years' duration, aimed at:-

(i) determining the natural composition of the stratosphere and assessing the changes which might arise from the operation of aircraft (supersonic aircraft in particular), and

(ii) assessing the meteorological effects, if any, consequent on these changes.

The terms of reference of the Committee restricted its work to the assessment of meteorological effects and consequently studies of possible biological, social and economic consequences were not attempted. The end point of the work was regarded as the prediction of the likely effects on the ozone in the stratosphere (which determines the amount of solar ultra-violet radiation penetrating to the earth's surface) and the magnitude of possible changes in climate, particularly surface temperature, which might arise as a result of increased aircraft operations in the stratosphere. The studies by COMESA produced a substantial increase of knowledge of the natural composition of the stratosphere and its governing processes and this enabled an assessment to be made of the general magnitude of the changes which might arise from the operation of stratospheric aircraft and the consequential meteorological effects. The COMESA report concluded that the possible effect on the ozone layer from comparatively small numbers of supersonic aircraft will not be detectable. However, the possibility remained of some effects if very large numbers of SSTs with present-day emission characteristics flew at higher operational altitudes and the effects of further expansion of stratospheric flight by subsonic aircraft of improved performance also required further study. The Committee therefore advised the continuance of research into the basic stratospheric processes particularly those relevant to the estimation of effects due to aircraft emissions. Further reports have since been produced by the COMESA workers in such areas as studies of the penetration of solar ultra-violet radiation to the surface, radiatior and general circulation models, 1-D modelling studies, the effects of nuclear tests on the ozone layer and the natural sources of NO_X in the stratosphere. Work has also been continued to improve

the representation of both photochemical and dynamical aspects in 1-D and 2-D models and a general programme of measurements of minor atmospheric constituents of importance in pollution studies has been started in the Meteorological Office.

EFFECTS OTHER THAN AIRCRAFT EMISSIONS

The possible effect of various chemicals released at the surface, particularly chlorofluorocarbons, on stratospheric ozone has since about 1974 become a subject of even more international concern. In view of this the U.K. Department of the Environment started a programme of work under contract at Atomic Energy Research Establishment (AERE) Harwell to study the effects of chlorofluorocarbons on stratospheric ozone. The programme includes laboratory studies of reaction rates and kinetics (eg hydroxyl reactions with various chlorocarbons), measurements of ground level concentrations of chlorofluorocarbons 11 and 12 and carbon tetrachloride, and aircraft sampling. In addition, Harwell has undertaken comprehensive one-dimensional modelling calculations using results obtained by their measurement programme and also assessed the results obtained in modelling studies elsewhere. The continuing work includes further studies of the role of chlorine nitrate in the ozone chemistry and also two-dimensional modelling of tropospheric composition.

Using results from this programme and other available scientific data the Central Unit on Environmental Pollution, Department of the Environment, published in April 1976 a report: Pollution Paper No 5 "Chlorofluorocarbons and their Effect on Stratospheric Ozone". The report concluded that, while scientifically many of the hypotheses put forward were plausible and warranted further attention, there was no immediate cause for precipitate action. It emphasised the need for a better understanding of the problem and in an attempt to reduce some of the uncertainties surrounding the matter it recommended that further research be undertaken within the next two years to help resolve some of the outstanding issues. In the meantime, it felt prudence demanded that attempts should be made by industry to seek alternatives which will meet the needs of the public and industry in general but which will not pose the same potential threat to the stratosphere. The results given in the U.S. National Academy of Sciences report "Halocarbons: Environmental Effects of Chlorofluoromethane Release" published 13 September 1976 were broadly the same and would appear to lead to rather similar conclusions.

STRATOSPHERIC RESEARCH ADVISORY COMMITTEE

In view of the range of stratospheric pollutants being discussed (which also may include other chlorine and bromine compounds, additional nitrogen oxide releases arising from the use of agricultural fertilisers and others) and their possible inter-reactions, the U.K. decided in May 1975 that interests in stratospheric pollution research could best be served by co-ordinating the various activities through a single governmental organisation. It was agreed the Central Unit on Environmental Pollution (CUEP) in the Department of the Environment should assume this role and in May 1976 a Stratospheric Research Advisory Committee was set up to advise the U.K. Government on co-ordinating stratospheric pollution research in the U.K. It comprised representatives from the U.K. Meteorological Office, AERE Harwell, Universities, Industry, Government Research Laboratories and Government Departments.

U.K. STRATOSPHERIC RESEARCH PROGRAMME

In addition to continuing basic studies of the natural stratosphere by the Meteorological Office, other Government agencies and the universities the U.K. Government is now supporting a specially organised programme of research into the effects of pollutants on stratospheric ozone. The programme can be divided into three main groups:-

(A) laboratory studies of the chemical kinetics of stratospheric species

(B) atmospheric measurements of trace species

(C) computer modelling techniques to predict the effects of stratospheric pollutants

This research is intended to provide a better understanding of the complex interaction of trace species both in the troposphere and stratosphere. Studies being, or soon to be supported include:

A. Chemical Kinetics

1. Laboratory studies on the detection of peroxyl (HO_2) radicals by laser magnetic resonance and extension of the technique to ClO and HCO radicals. The work will give information on absorption spectra, absorption coefficients and reaction rates of these species.

2. Studies of the reaction rates of ClO and Cl with NO_2 and their variations with temperature and pressure leading to an elucidation of the ClO, NO_2 reaction as a possible sink for chlorofluorocarbons.

3. Studies of the reactions of free radical species remaining after the initial chlorine radical is removed from chlorofluorocarbons 11 and 12, including studies of the behaviour of $COCl_2$, COF_2 and COFCl.

B. Atmospheric Measurements

4. Continued measurement of chlorofluorocarbons and other halocarbons at ground level in the U.K. to establish background concentrations, long term trends and atmospheric residence times.

5. Measurement of tropospheric concentrations of nitrous oxide on an automatic basis to establish the magnitude of any N_2O source at ground surface.

6. Shipboard measurements of oxides of nitrogen, methyl chloride and methyl bromide in the atmosphere and coastal waters around the U.K. to estimate the role of the ocean as a source/sink of atmospheric halocarbons and nitrous oxide.

7. A programme of upper air sample collection and measurement using commercial flights of Concorde. This will concentrate on the measurement of stable species including halocarbons, nitrous oxide and carbon monoxide. Emphasis will be on the collection of well standardised data at frequent intervals for the determining of vertical profiles up to 55,000 feet including an investigation of the statistical variations and inter-relationships between individual chemical species and with stratospheric ozone.

C. Computer Modelling Studies

8. Maintenance of a one-dimensional computer modelling capability to permit rapid assessment of the implications of new kinetic data on ozone depletion calculations and to provide some input parameters for two-dimensional models.

9. A two-dimensional modelling programme to study the effects of meridional and vertical mean and eddy motions and their interaction with the chemical kinetics. A simplified model with 3 vertical columns is also contemplated which will allow insertion of surface releases into the simulated atmosphere at realistic latitudes, incorporating some meridional as well as vertical transport together with a detailed photochemical scheme of the type used in 1-D models. This simplified model will allow more experimental determinations to be made than are possible with the full 2-D model.

10. A two-dimensional modelling programme of the transport features of chlorofluorocarbons in the stratosphere including an evaluation of the treatment of chlorofluorocarbons both as inert tracers and with parameterised destruction by photochemical reactions for residence time studies.

ON-GOING U.K. CONTRIBUTIONS TO STRATOSPHERIC MONITORING

In addition to its regular measurements at radio-sonde stations of wind and temperature up to about 25km in the global network primarily for weather forecasting and climatological purposes the U.K. Meteorological Office is continuing to maintain four stations making total ozone measurements using the Dobson spectrophotometer. These are located at Bracknell and Lerwick in the U.K., St. Helena, and Mahe (Seychelles). At present it appears likely that the long term series of regular ozone observations at Oxford will have to be discontinued and those at Bracknell used to continue the record for central England. In addition measurements are also being made by the British Antarctic Survey (BAS) at their Antarctic stations Halley Bay, Argentine Island and S. Georgia. All the regular U.K. observations are transmitted to the World Weather Centre in Toronto for inclusion in the global record and general distribution. The U.K. also cooperates internationally in the World Meteorological Organisation's studies relating to the ozone layer and the standardisation of observations.

Apart from the planned use of Concorde aircraft to obtain data on other stratospheric constituents all the other U.K. measurements at present being made or planned are primarily for research purposes. The U.K. Meteorological Office operates a Meteorological Research Flight at Farnborough which carries out limited flight programmes to measure stratospheric humidity and ozone and possibly other constituents, a rocket launching station at South Uist where measurements of wind and temperature are made for special studies such as stratospheric sudden warming phenomena and calibration of satellite measurements and also has a laser installation which is useful for aerosol studies. Teams from Oxford University and the National Physical Laboratory also collaborate in International Projects studying the stratosphere using large balloons and satellites. The Oxford measurements of global stratospheric temperature fields using the Nimbus D and E satellites have been followed by the higher altitude measurements from Nimbus F. In addition Oxford and NPL will be cooperating in the use of Nimbus 6 and also Space Lab. in the future to obtain new global measurements of several stratospheric constituents. Studies are also being made by the Meteorological Office to extend the use of satellite observations to be obtained from Tiros N, Meteosat and others for operational purposes.

CONCLUSIONS

The U.K. has contributed very considerably to present understanding of the stratosphere and intends to continue actively its studies both of natural processes and the likely effects of pollutants in this region of the atmosphere. At present it is devoting considerable resources both to national studies and international collaboration through its Tripartite Agreement with the U.S.A. and France, work within the European Economic Community and cooperation in the World Meteorological Organisation. There is however considerable scope for expansion of these activities and increased collaboration with scientists of other nations particularly in the area of stratospheric measurements if adequate funding were made available.